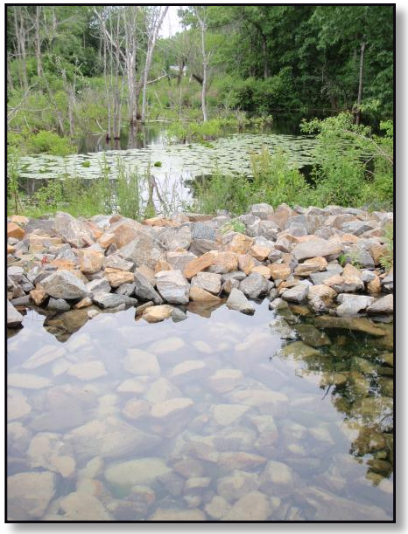
Cold Climate Performance and Optimization of Bioretention Soil Mix for Nutrient Removal Michigan Green Infrastructure Conference

May 9, 2014

UNH Stormwater Center, Environmental Research Group,
Department of Civil Engineering
University of New Hampshire



Special Thanks

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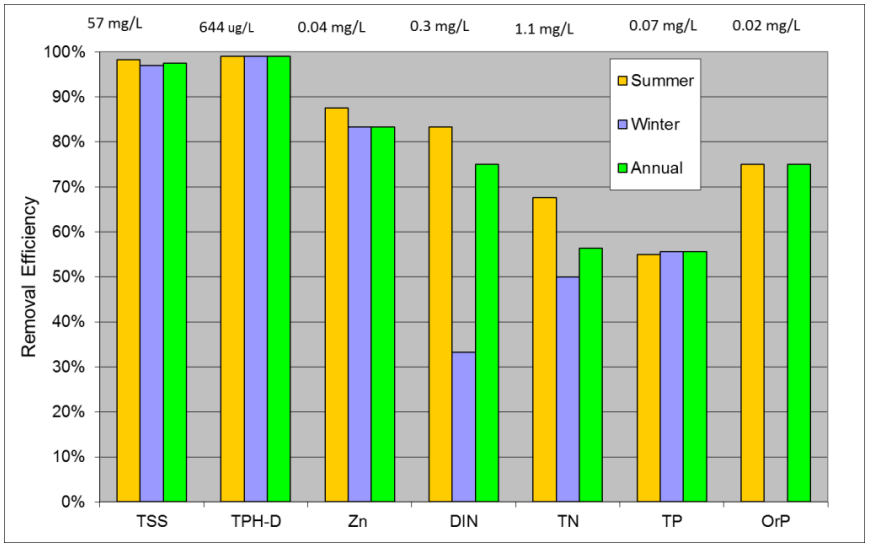
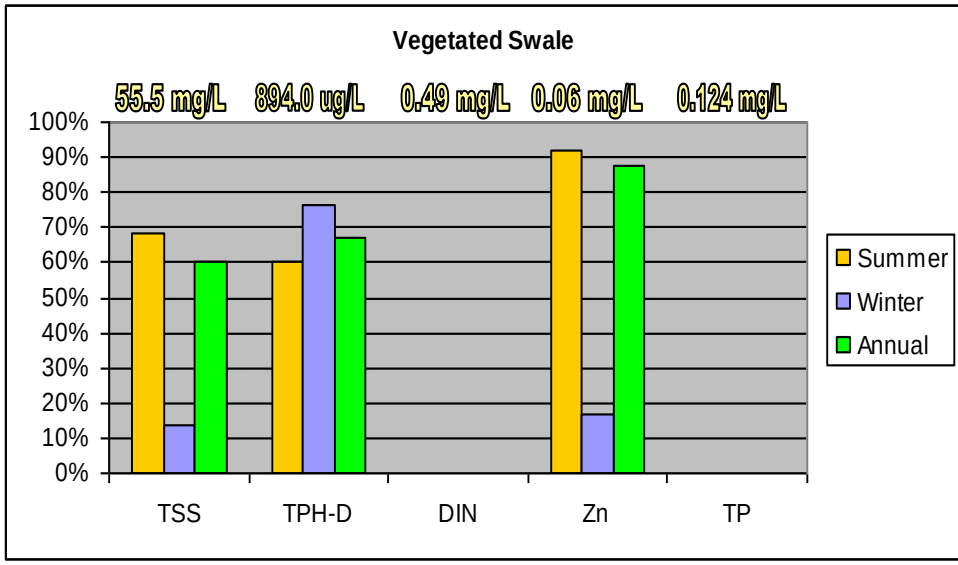
Robin Stone – UNHSC
Funders:
CICEET
NH DES
EPA Region 1
Stantec

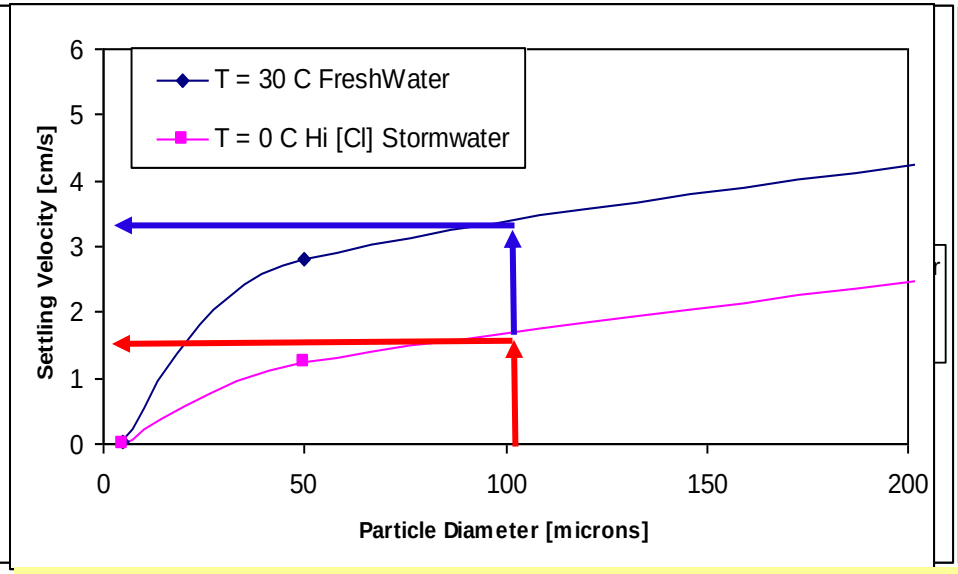

Cold Climate
Performance Results

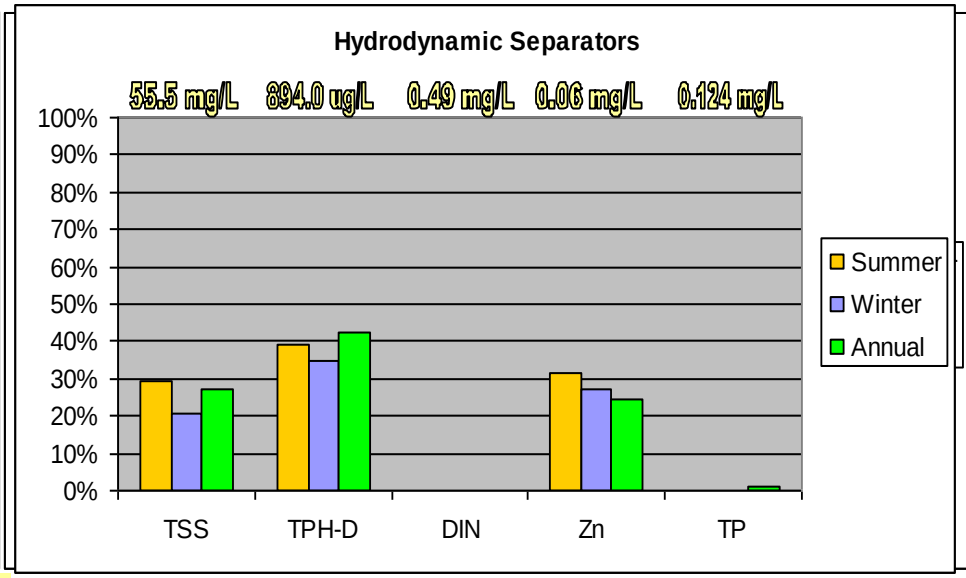
Seasonal Variations in Performance



Subsurface Gravel Wetland





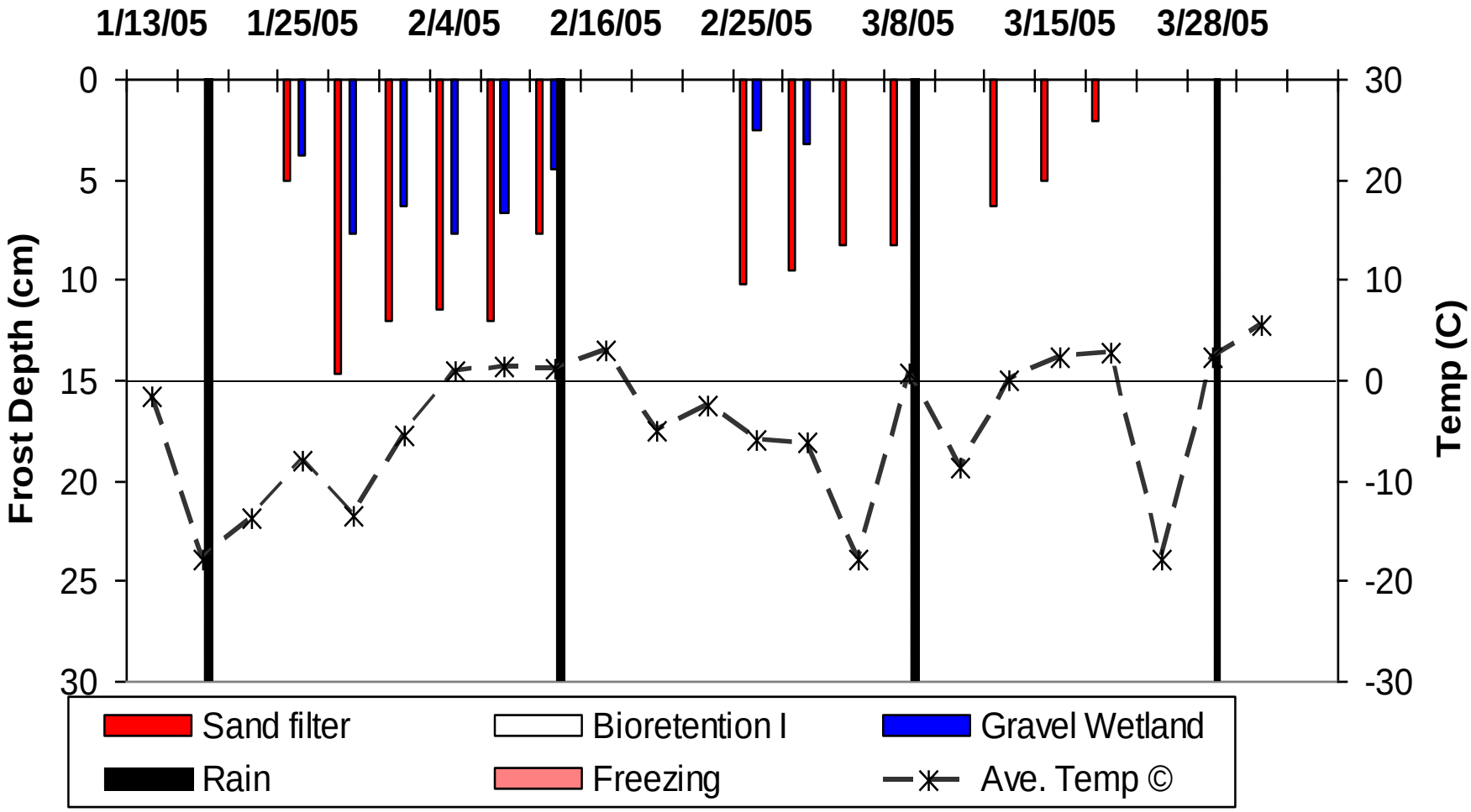


The effect of T and [Cl^-] is to nearly double the settling time from 1.6 to 3.4 cm/sec

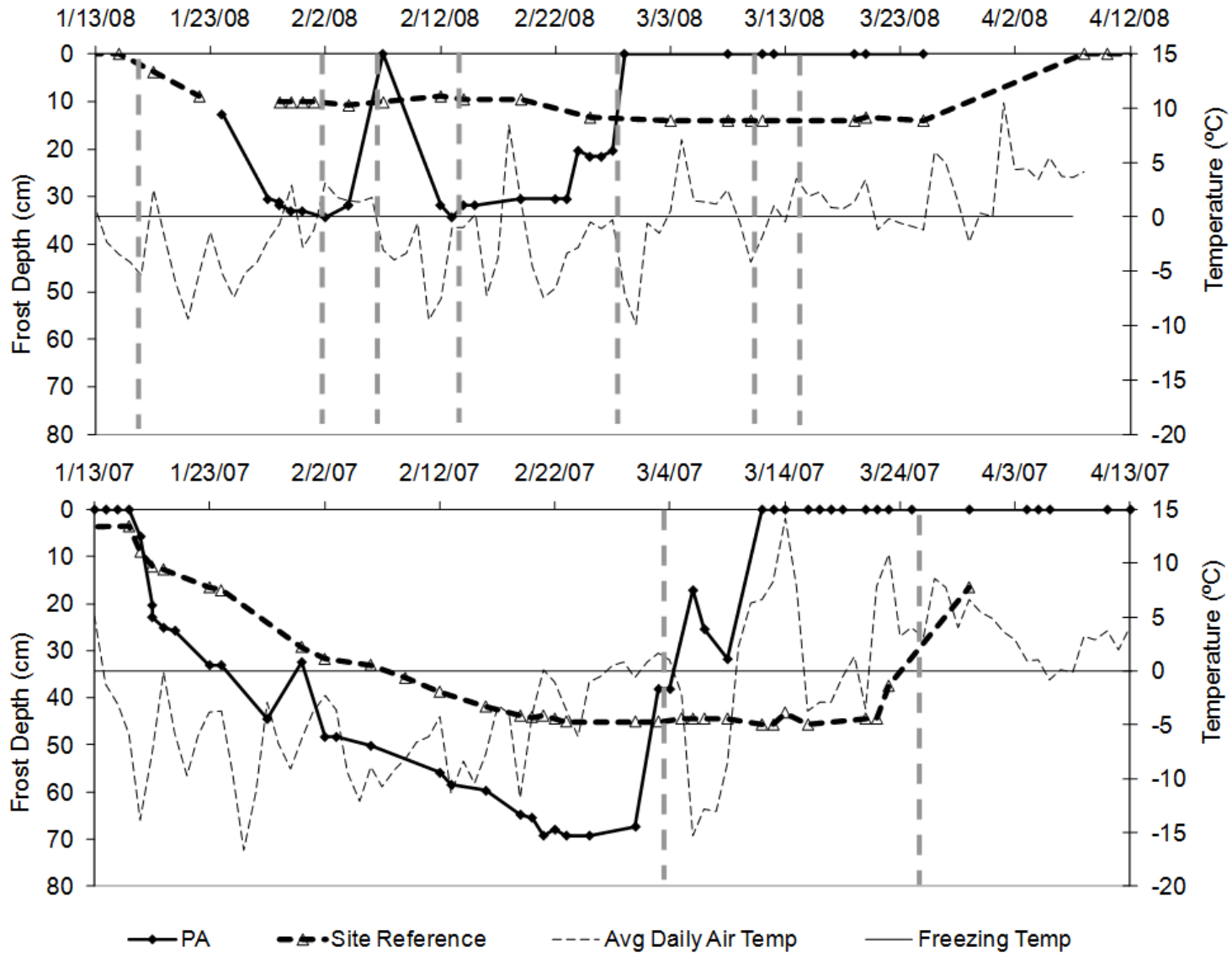
Frost Penetration

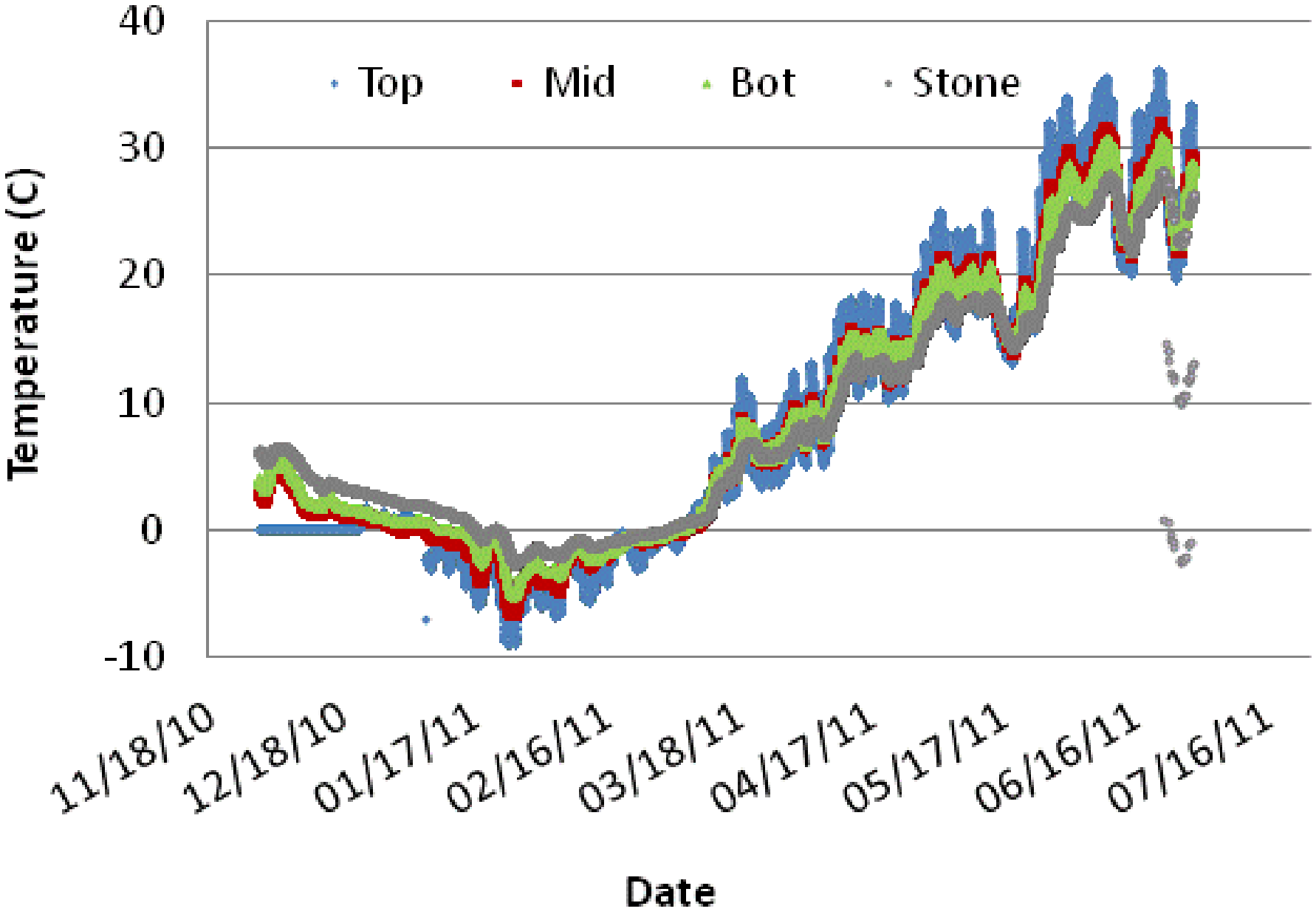
- Can be related to pavement failure
- Measured with a ‘field-assembled’ frost gauge (Ricard et al., 1976)
- Show relationships between pavements and soils

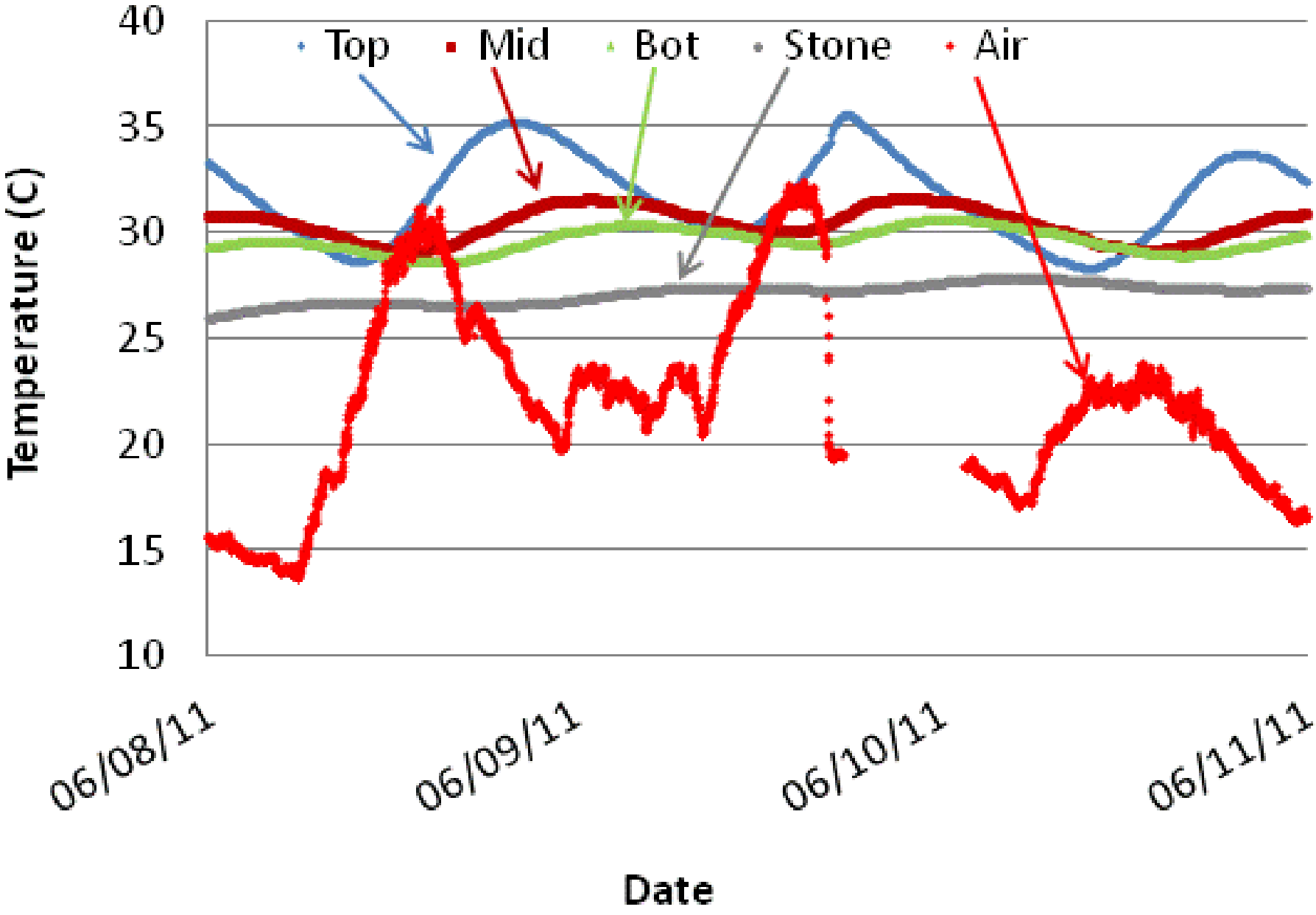
Filtration Systems Frost Penetration



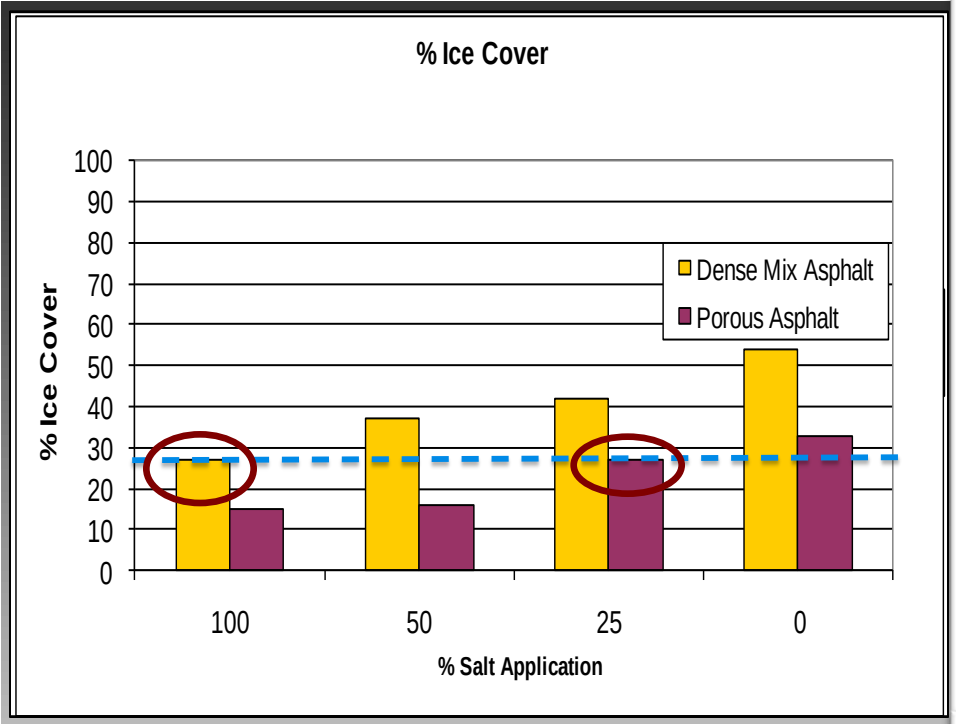
Porous Asphalt Frost Penetration



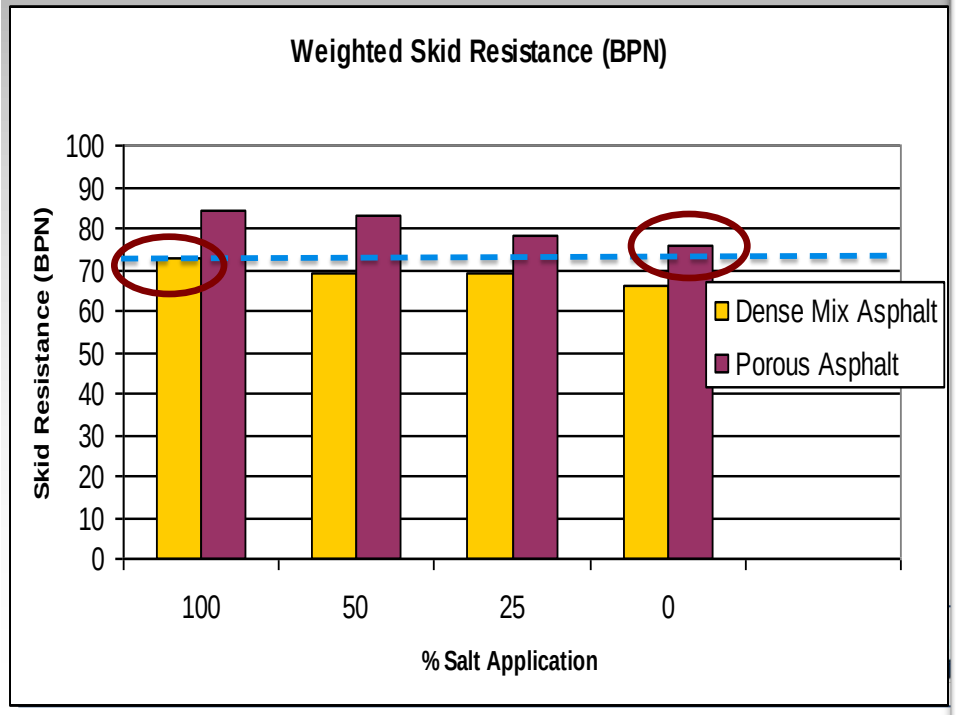

40
30
20
10
0
-10
Temperature (C)
Top
Mid
Bot
Stone
11/18/10
12/18/10
01/17/11
02/16/11
03/18/11
04/17/11
05/17/11
06/16/11
07/16/11
Date


Top
Mid
Bot
Stone
Air
40
35
30
25
20
15
10
Temperature (C)
06/08/11
06/09/11
06/10/11
06/11/11
Date

Winter Maintenance & Salt Reduction


% Ice Cover
100
90
80
70
60
50
40
30
20
10
0
% Ice Cover
Dense Mix Asphalt
Porous Asphalt
100
50
25
0
% Salt Application


DMA after spring rain on snow event


Weighted Skid Resistance (BPN)
100
90
80
70
60
50
40
30
20
10
0
Skid Resistance (BPN)
Dense Mix Asphalt
Porous Asphalt
100
50
25
0
% Salt Application


PA after spring rain on snow event

Effective Salt Reductions

Pavement Type	2006-2007		2007-2008		Reductions when compared to DMA 100% App. Rate	
	Anti-Icing Apps.	Deicing Apps.	Anti-Icing Apps.	Deicing Apps.	App. Rate	Average Mass Reduction * ('06-'08)
DMA	15	14	23	22	100%	0%
PA	15	6	23	27	25%	75%
PC - shade	-	-	23	31	100%	-20%
PC - sun	-	-	23	23	100%	-2%

* Reduction possible with no loss in skid resistance (safety)

Pervious Concrete Spalling

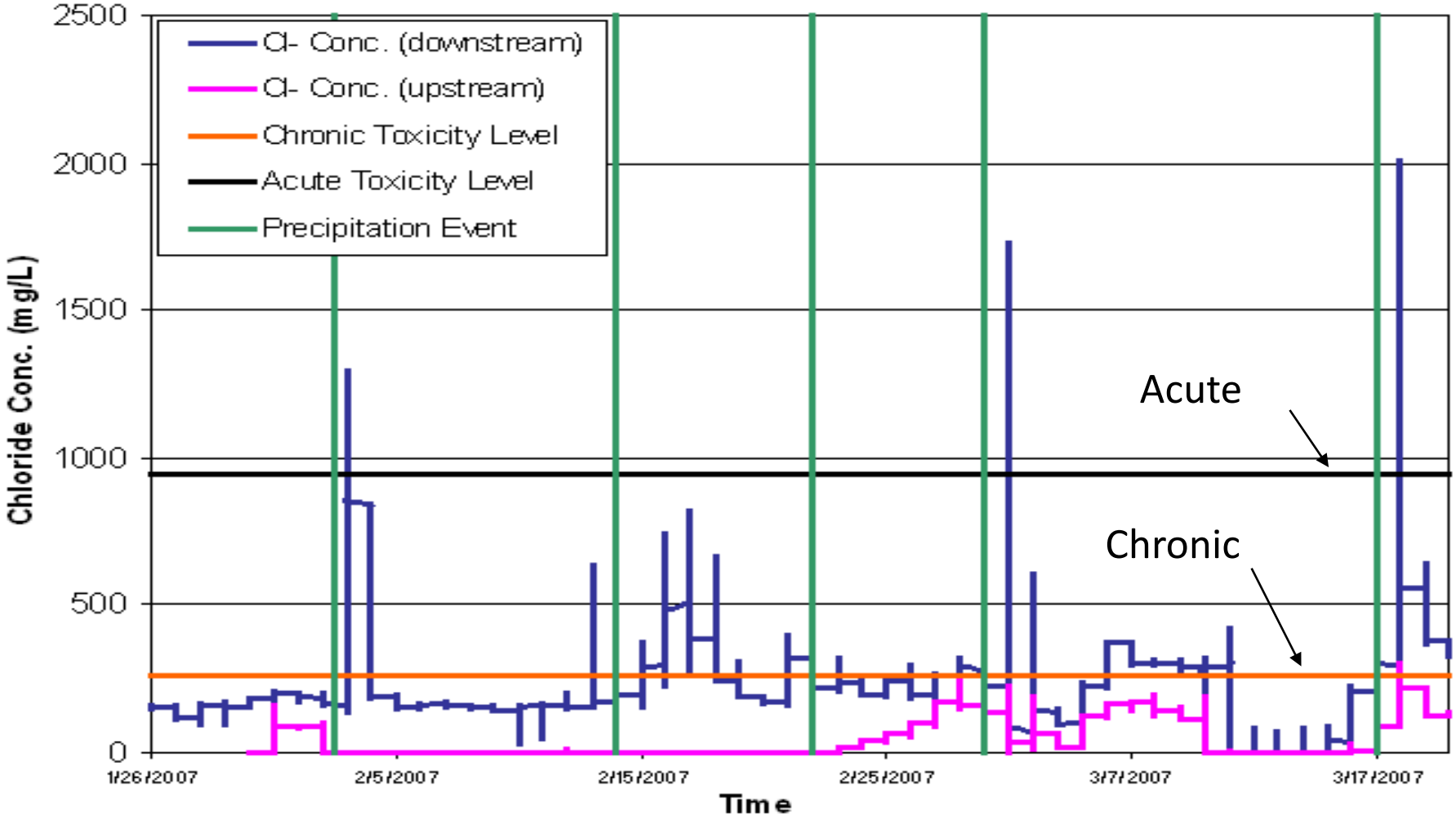

28D N83
U.S.
MARINES

The PC Verdict

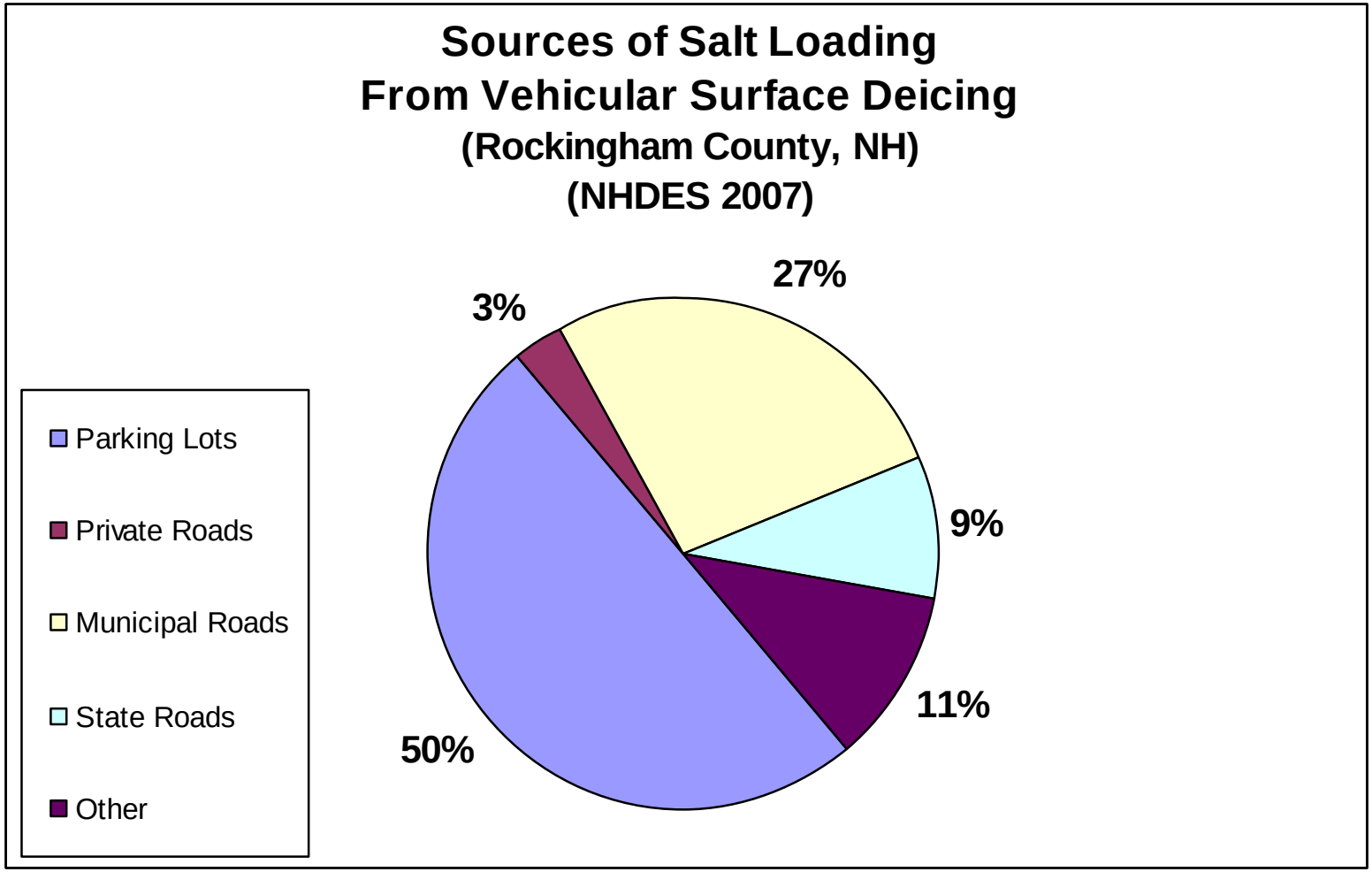
There are 3 main curing requirements for PC:

- 7 day cure for structural load
- 28 day cure to protect against freeze-thaw damage,
- 12 month cure prior to aggressive chloride deicing applications.

Chloride Levels in First Order Receiving Stream (Durham, NH)

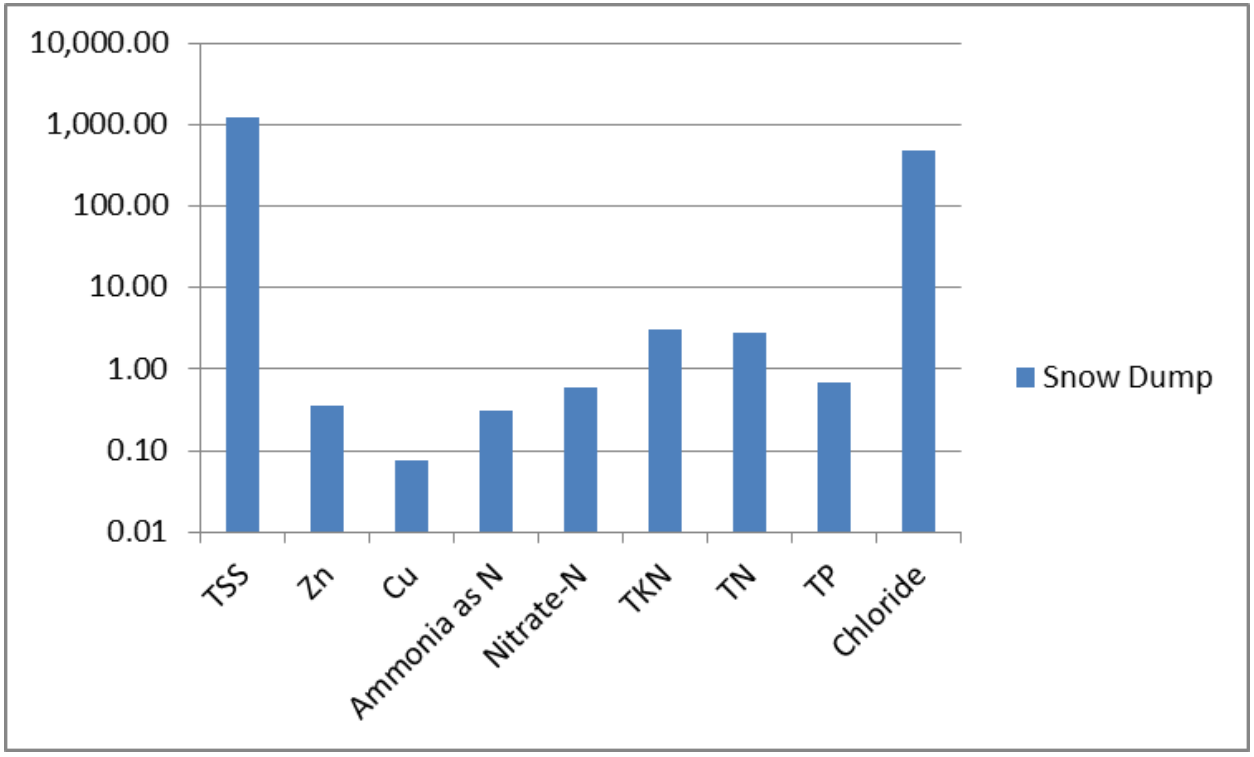


Where should reductions occur?




Renaud

Portsmouth Snow Dump Concentration Calculations

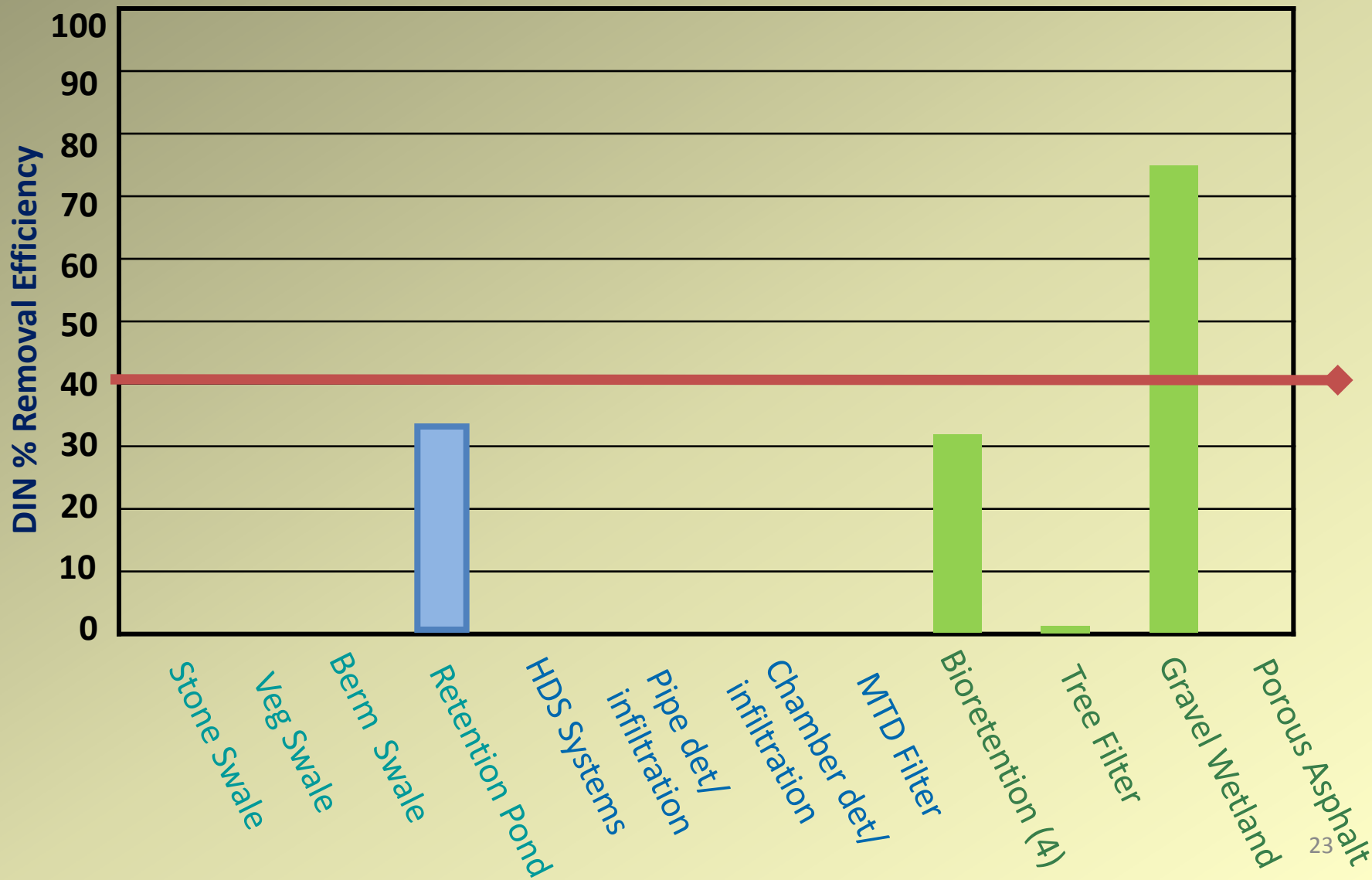


Portsmouth Snow Dump Load Calculations

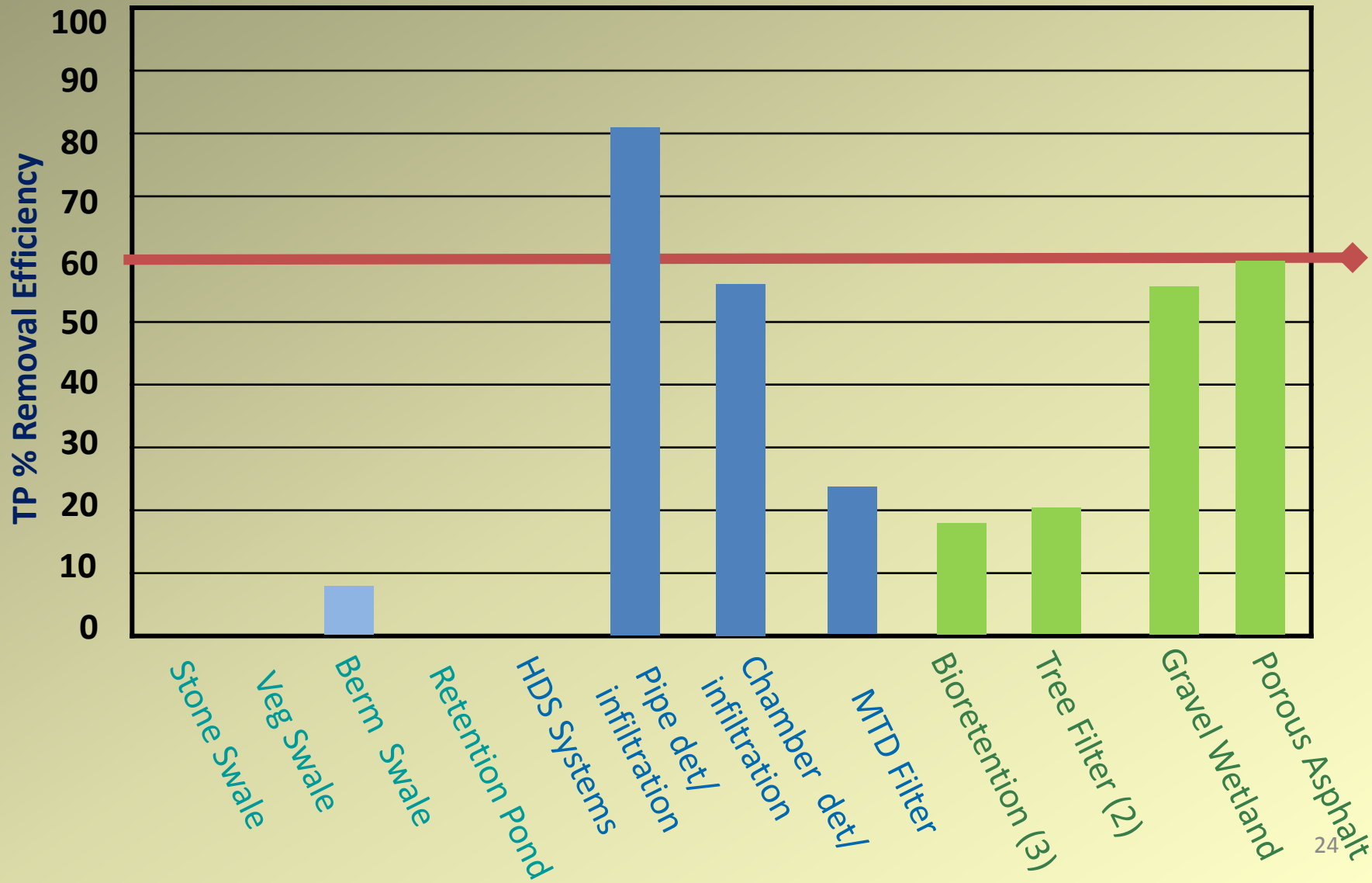
POLLUTANT LOAD ESTIMATES

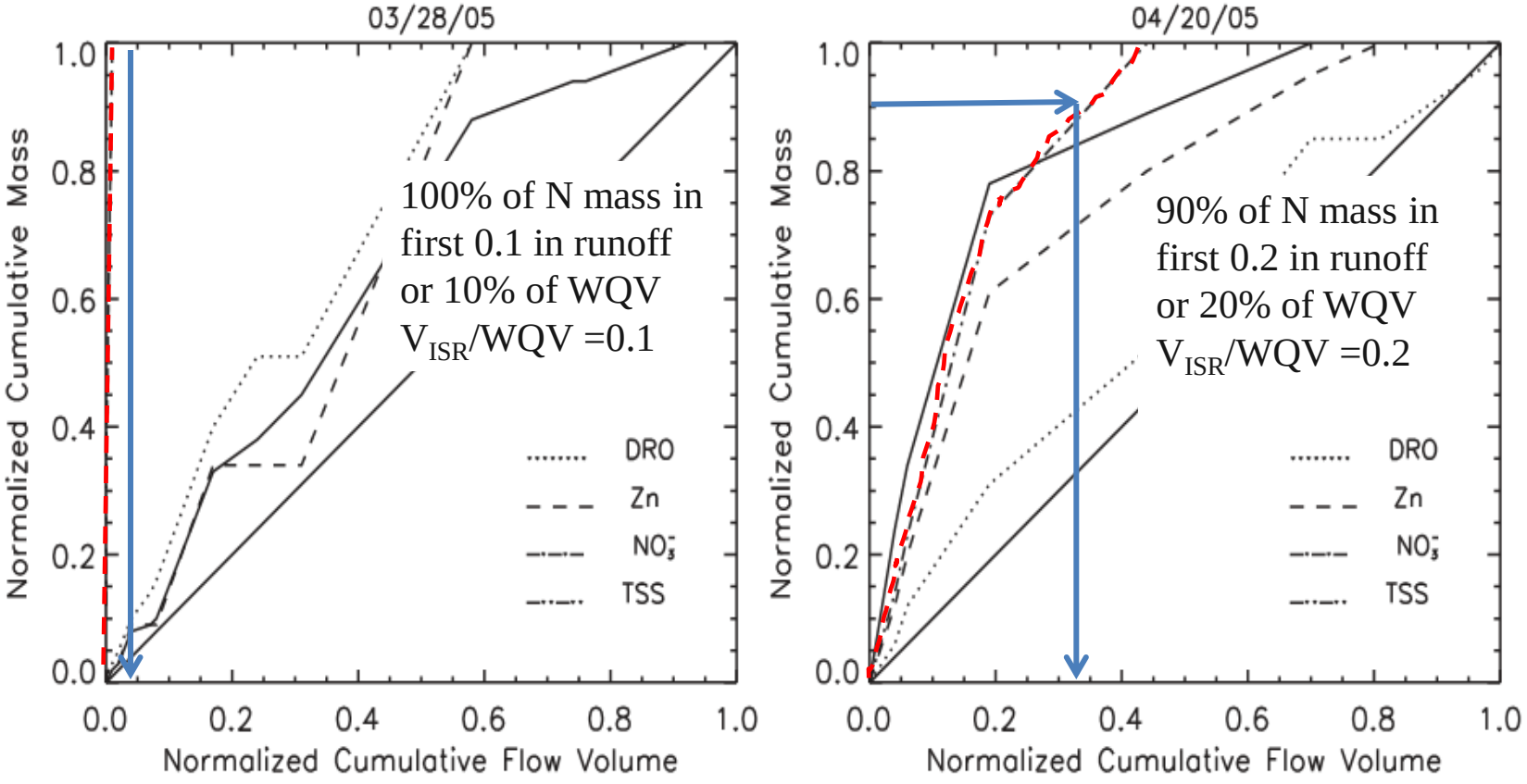
	TSS	Zn	Cu	Ammonia as N	Nitrate-N	TKN	TN	TP	Chloride
	(lb)	(lb)	(lb)	(lb)	(lb)	(lb)	(lb)	(lb)	(lb)
n	11	12	12	12	5	12	12	12	11
MIN	3856	0	1	6	16	42	42	1	10
MED	33055	12	2	13	21	115	100	33	503
MAX	215587	39	9	32	64	498	498	70	105048
AVERAGE	**55134**	**15**	**3**	**15**	**28**	**143**	**135**	**30**	**19240**
ST. DEV	56735	13	2	8	18	114	118	20	35714

DIN Removal Efficiencies

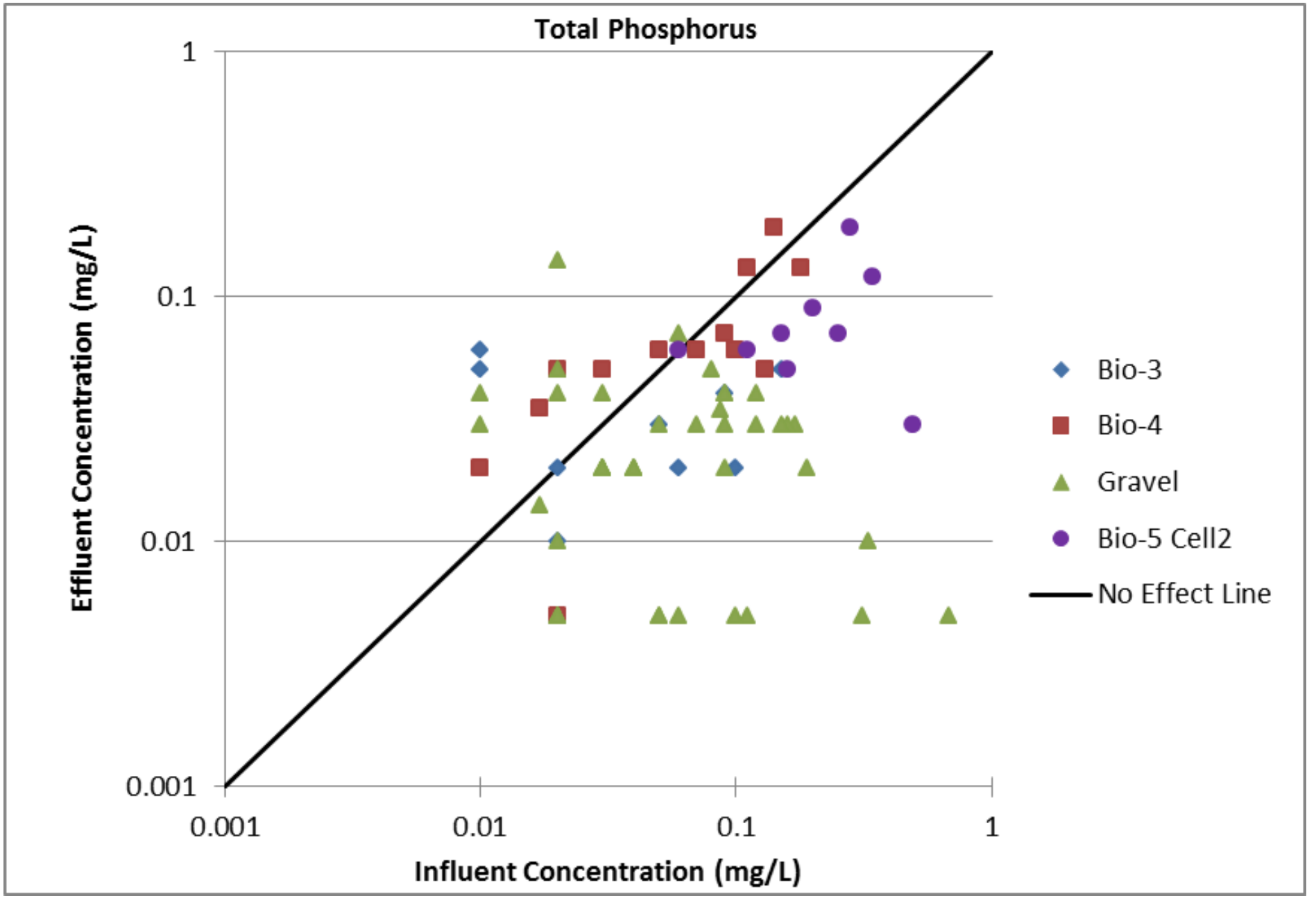


TP Removal Efficiencies





Mass loading for DRO, Zn, NO3, TSS as a function of normalized storm volume for two storms: (a) a large 2.3 in rainfall over 1685 minutes; (b) a smaller 0.6 in storm depth over 490 minute. DRO=diesel range organics, Zn= zinc, NO3= nitrate, TSS= total suspended solids


Total Phosphorus
Effluent Concentration (mg/L)
1
0.1
0.01
0.001
0.001
0.01
0.1
1
Influent Concentration (mg/L)
Bio-3
Bio-4
Gravel
Bio-5 Cell2
No Effect Line

Unit Operations & Processes (UOPs) in the Gravel Wetland

- Physical Operations
- Biological Processes
- Chemical Processes
- Hydrologic Operations

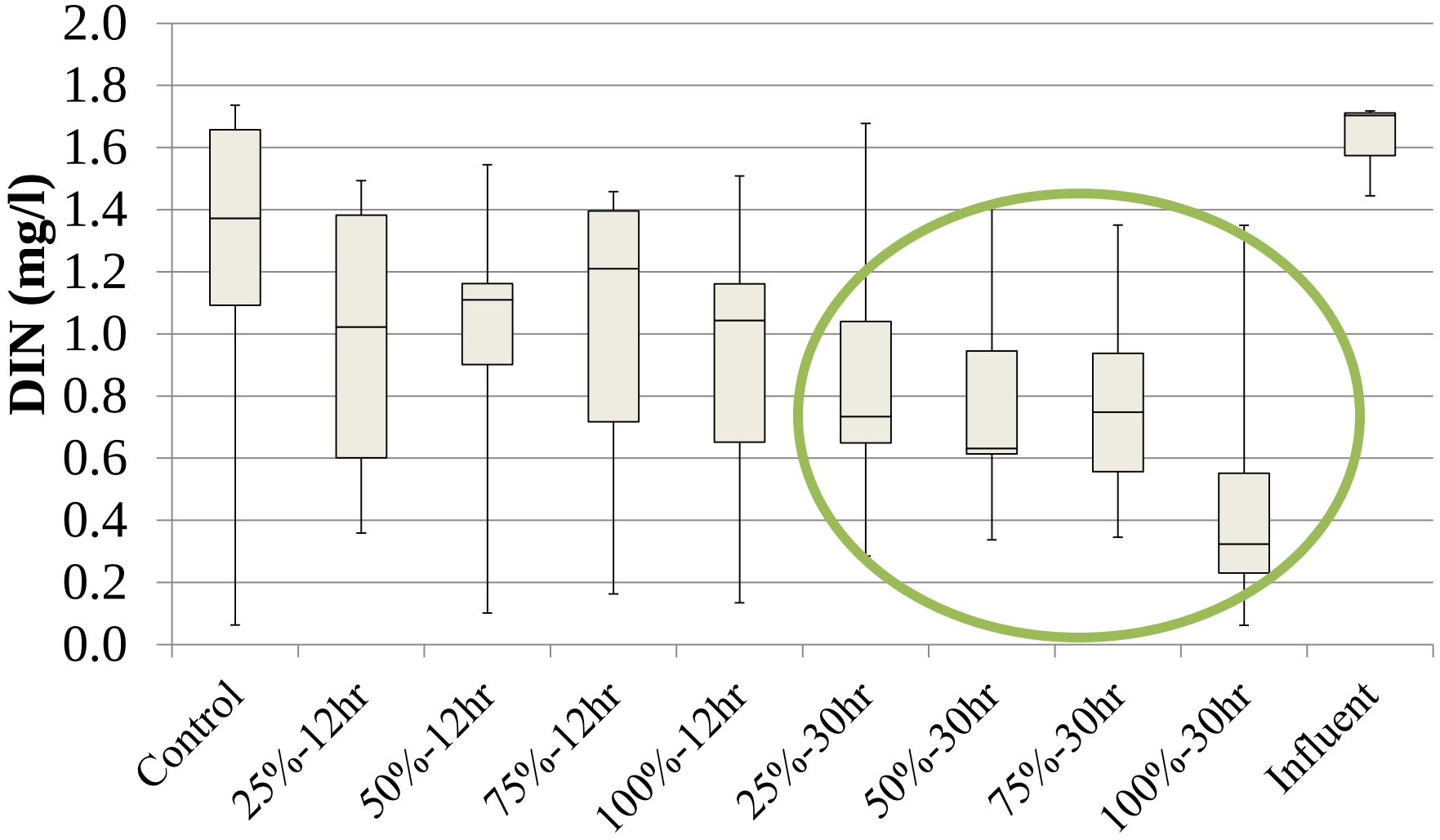
Experimental Design

Phase 1: Test Drain time and ISR:WQV Ratio

Phase 2: Test bioretention soil mix and four different soil amendments

Phase 3: optimize the ratio of loam to sand for P removal, as well as to further optimize the soil to soil amendment ratio for top mixes (Fe_2 and WTR)

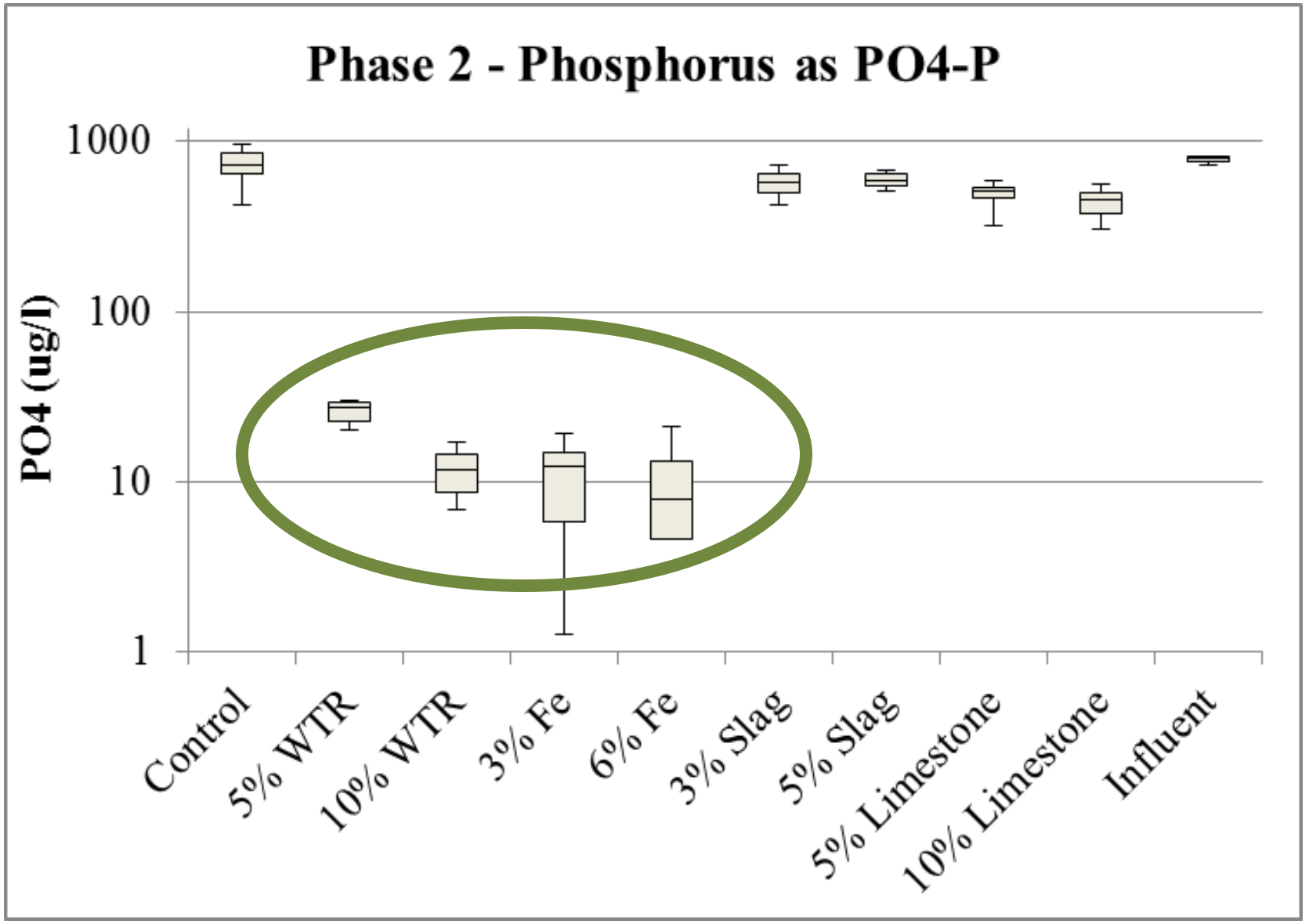
Nitrogen Results

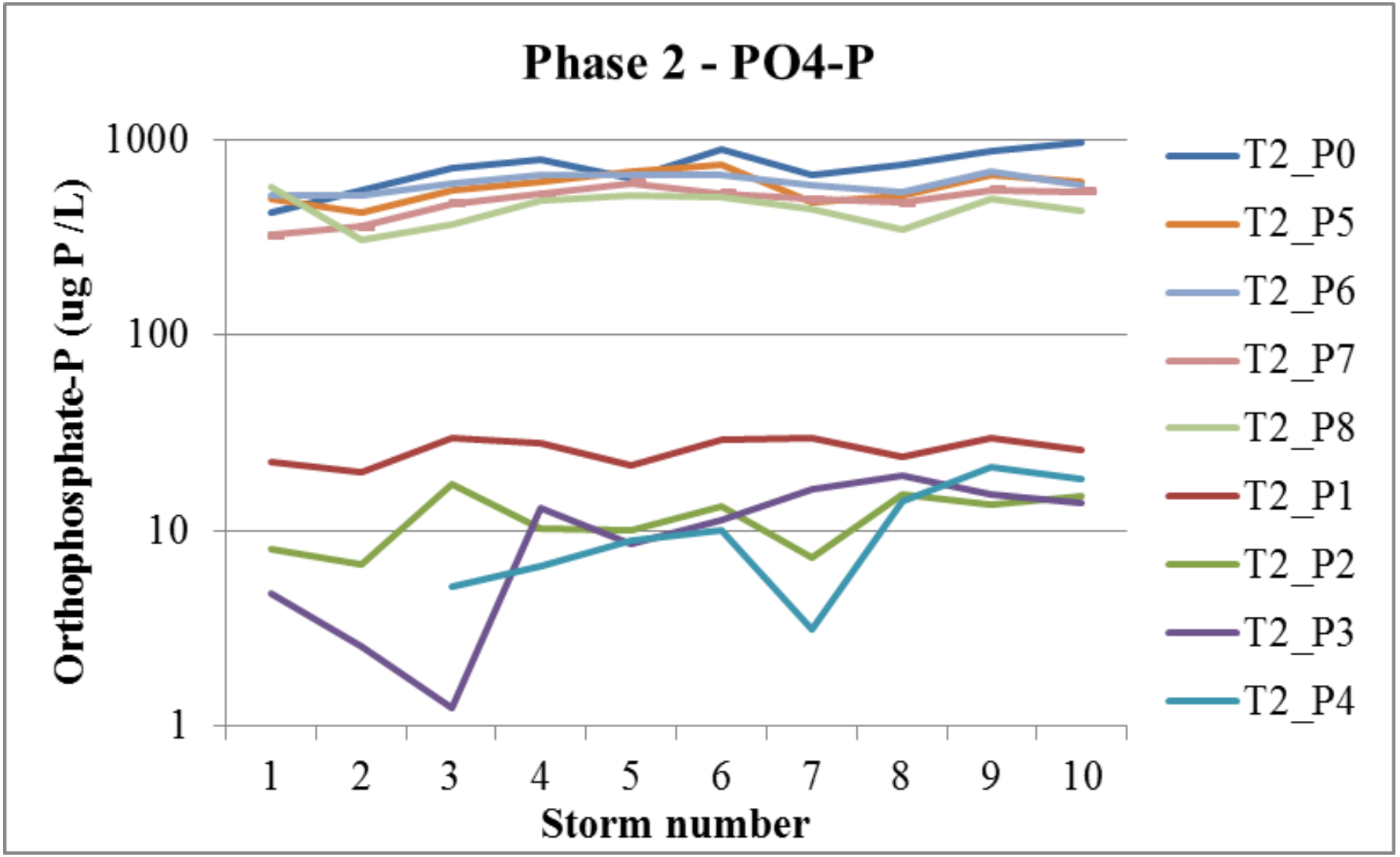


Phase 2: Phosphorus

Column #	Soil Mix	Notes
T2-P0	UNHSC BSM (control)	• Drainage to filter ratio 80:1 • Soil depth in columns: 24” • 24 hour drain time • Soil tested: UNHSC mix
T2-P1	UNHSC 95% BSM + 5% WTR	
T2-P2	UNHSC 90% BSM + 10% WTR	
T2-P3	UNHSC 97% BSM+3% Fe_2	
T2-P4	UNHSC 94% BSM+6% Fe_2	
T2-P5	UNHSC 97% BSM+3% Slag	
T2-P6	UNHSC 95% BSM+5% Slag	
T2-P7	UNHSC 95% BSM +5% Limestone	
T2-P8	UNHSC 90% BSM +10% Limestone	

Phosphorus Results

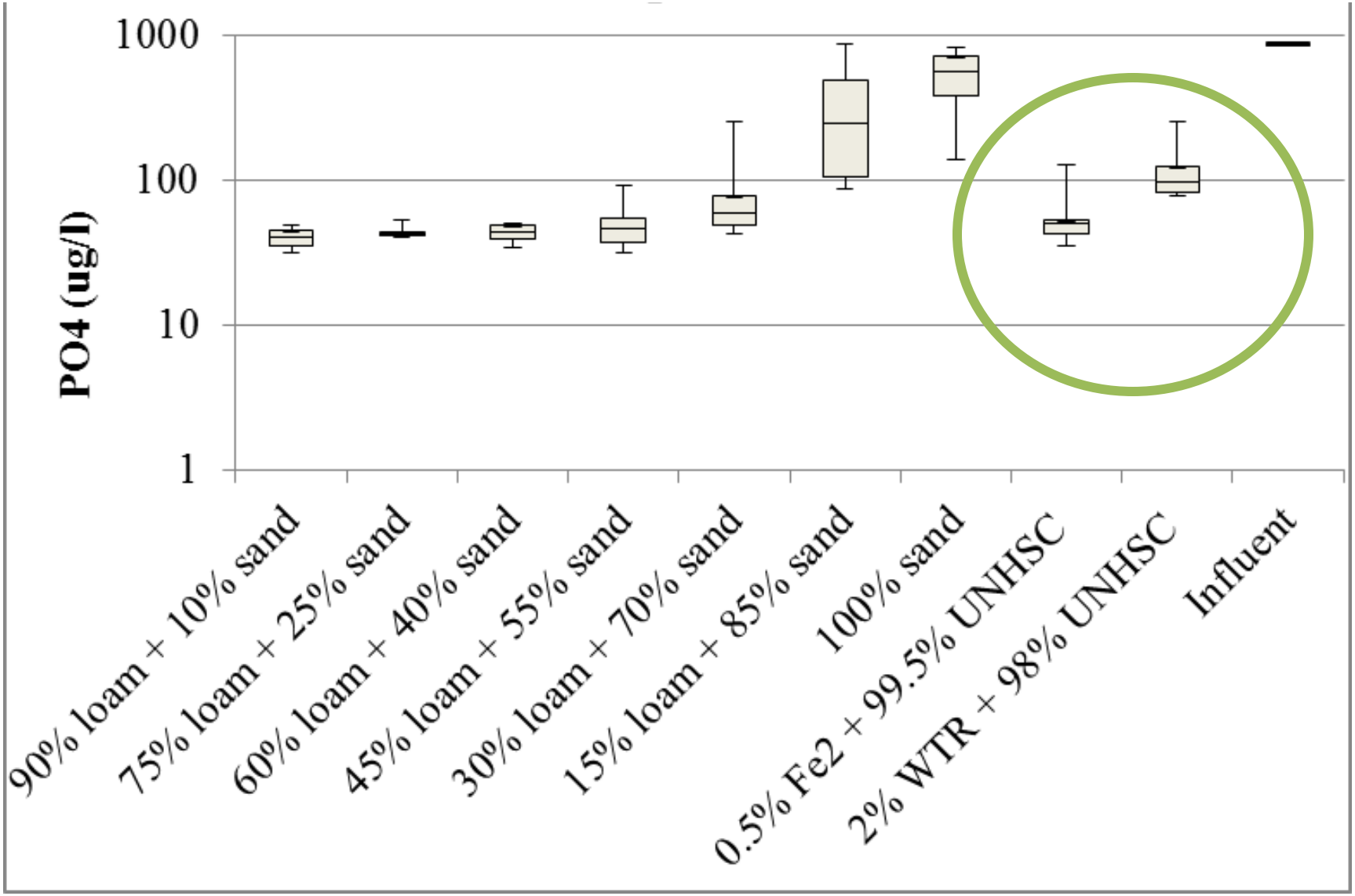



Phase 2 - PO4-P
Orthophosphate-P (ug P /L)
1000
100
10
1
1
2
3
4
5
6
7
8
9
10
Storm number
T2_P0
T2_P5
T2_P6
T2_P7
T2_P8
T2_P1
T2_P2
T2_P3
T2_P4

Phase 3: Phosphorus Optimization

Column #	Soil Mix	Notes
T4-P1	90% Stantec loam + 10% sand	• Drainage to filter ratio 25:1 • Soil depth: 12” • Percentage of amending materials was based on test results from Phases 2 and 3
T4-P2	75% Stantec loam + 25% sand	
T4-P3	60% Stantec loam + 40% sand	
T4-P4	45% Stantec loam + 55% sand	
T4-P5	30% Stantec loam + 70% sand	
T4-P6	15% Stantec loam + 85% sand	
T4-P7	100% sand	
T4-P8	0.5% Fe_2 + 99.5% UNHSC mix	
T4-P9	2% WTR + 98% UNHSC mix	

Optimization Results



Conclusions - the obvious!

- Cold climate conditions impact all BMPs
- Compost leaches nutrients
- Filters are superior at sediment removal
- Hydraulic loading ratio and retention time have a large influence on performance

Conclusions – the promising…

- LID filtration systems have demonstrate lower vulnerabilities to cold climate impacts
- Modified bio systems show remarkable improvements to DIN and Ortho-P removals in the lab and in the field: ~ 60 - >90%
- Nitrogen removal is less media dependent and improves with ISR and with longer retention
- Loam has an excellent P-sorp capacity and should be incorporated in higher proportions in BSM

Conclusions – the curious…

- Details regarding BSM components are vague at best
- If optimal RE are to be achieved designs should be fine tuned and systems maintained


Questions?